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Mauro et al.

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(54) **TRANSLATION ENHANCER-ELEMENT DEPENDENT VECTOR SYSTEMS**

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**

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C07H 21/02	(2006.01)
C07H 21/04	(2006.01)
C12N 15/85	(2006.01)
C12N 15/10	(2006.01)
C12N 15/67	(2006.01)

(52) **U.S. Cl.**

CPC ***C12N 15/85*** (2013.01); ***C12N 15/1051*** (2013.01); ***C12N 15/1086*** (2013.01); ***C12N 15/67*** (2013.01); *C12N 2800/107* (2013.01); *C12N 2830/002* (2013.01); *C12N 2840/105* (2013.01); *C12N 2840/20* (2013.01); *C12N 2840/203* (2013.01)

(58) **Field of Classification Search**

CPC C12N 15/85; C12N 15/1051; C12N 15/1086; C12N 2800/107; C12N 2830/002; C12N 2840/105; C12N 2840/20; C12N 2840/203

USPC 435/320.1; 536/23.1, 24.1

See application file for complete search history.

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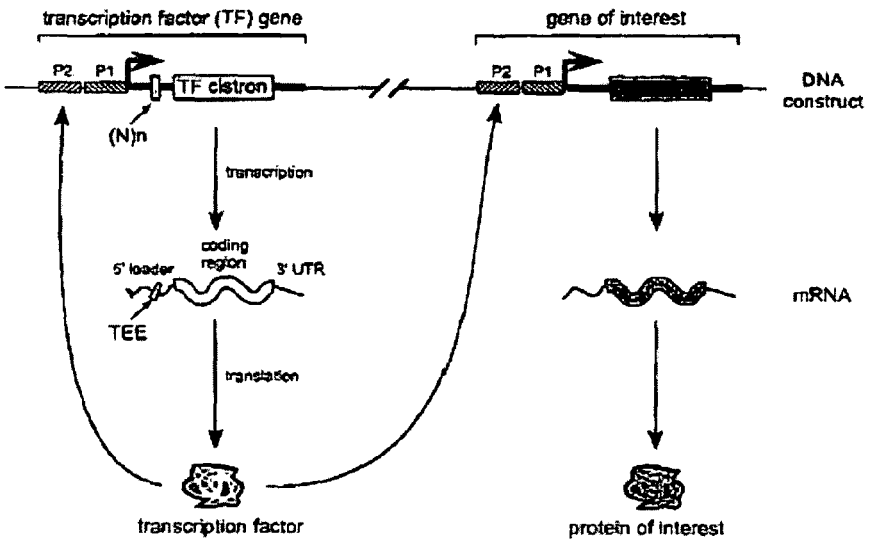
(57) **ABSTRACT**

A translation enhancer-driven positive feedback vector system is disclosed which is designed to facilitate identification of a Translational Enhancer Element (TEE) and to provide a means for overexpression of gene products. The system exploits both transcriptional and translational approaches to control the expression levels of genes and/or gene products. Methods are also disclosed for screening libraries of random nucleotide sequences to identify translational elements and for overproduction of proteins, which have uses in both research and industrial environments.

8 Claims, 12 Drawing Sheets



Promoter elements:

P1: - minimal promoter (TATA)
- regulatable promoter

P2: - upstream activating sequence (UAS; one to multiple copies)
- T7 promoter
- other transcription elements

Transcription factor genes:

- GAL4, GAL4/VP16
- T7 RNA polymerase
- other transcription factors

Genes of interest:

- fluorescent protein genes (e.g. enhanced green fluorescent protein; EGFP)
- luciferase genes (*Renilla* or *Photinus*)
- therapeutic protein (e.g. monoclonal antibodies)

Figure 1

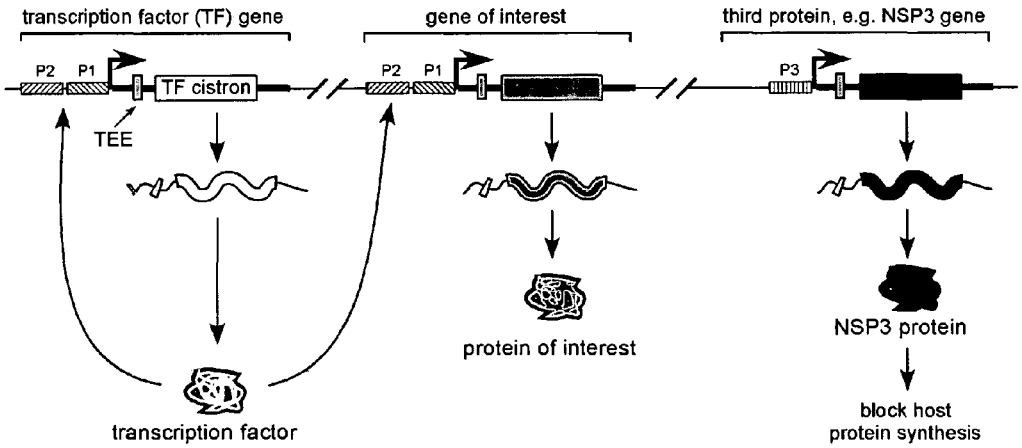

transcription factor (TF) gene
gene of interest
third protein, e.g. NSP3 gene
P2
P1
TF cistron
TEE
P2
P1
P3
protein of interest
NSP3 protein
block host
protein synthesis
transcription factor

Figure 2

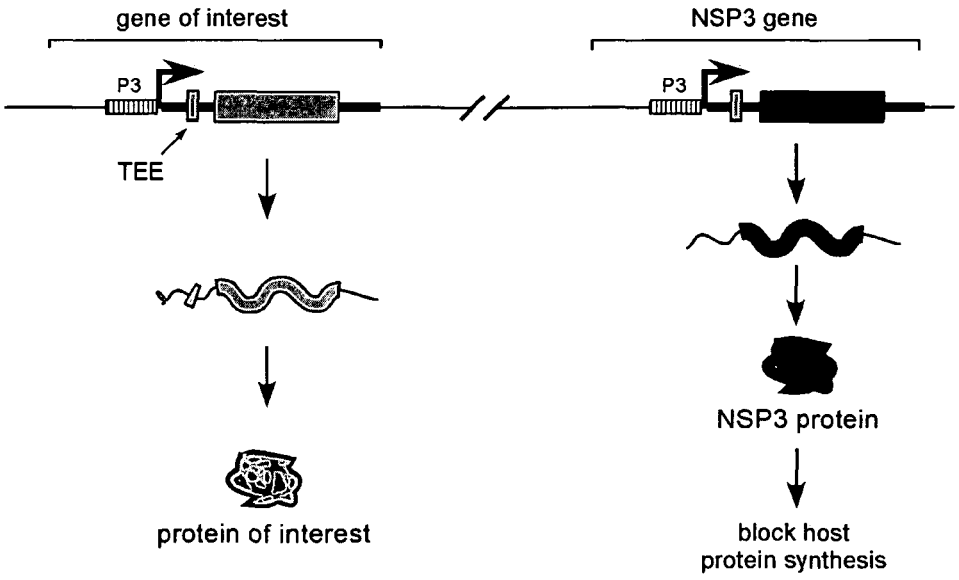

gene of interest
NSP3 gene
P3
P3
TEE
NSP3 protein
protein of interest
block host
protein synthesis

Figure 3

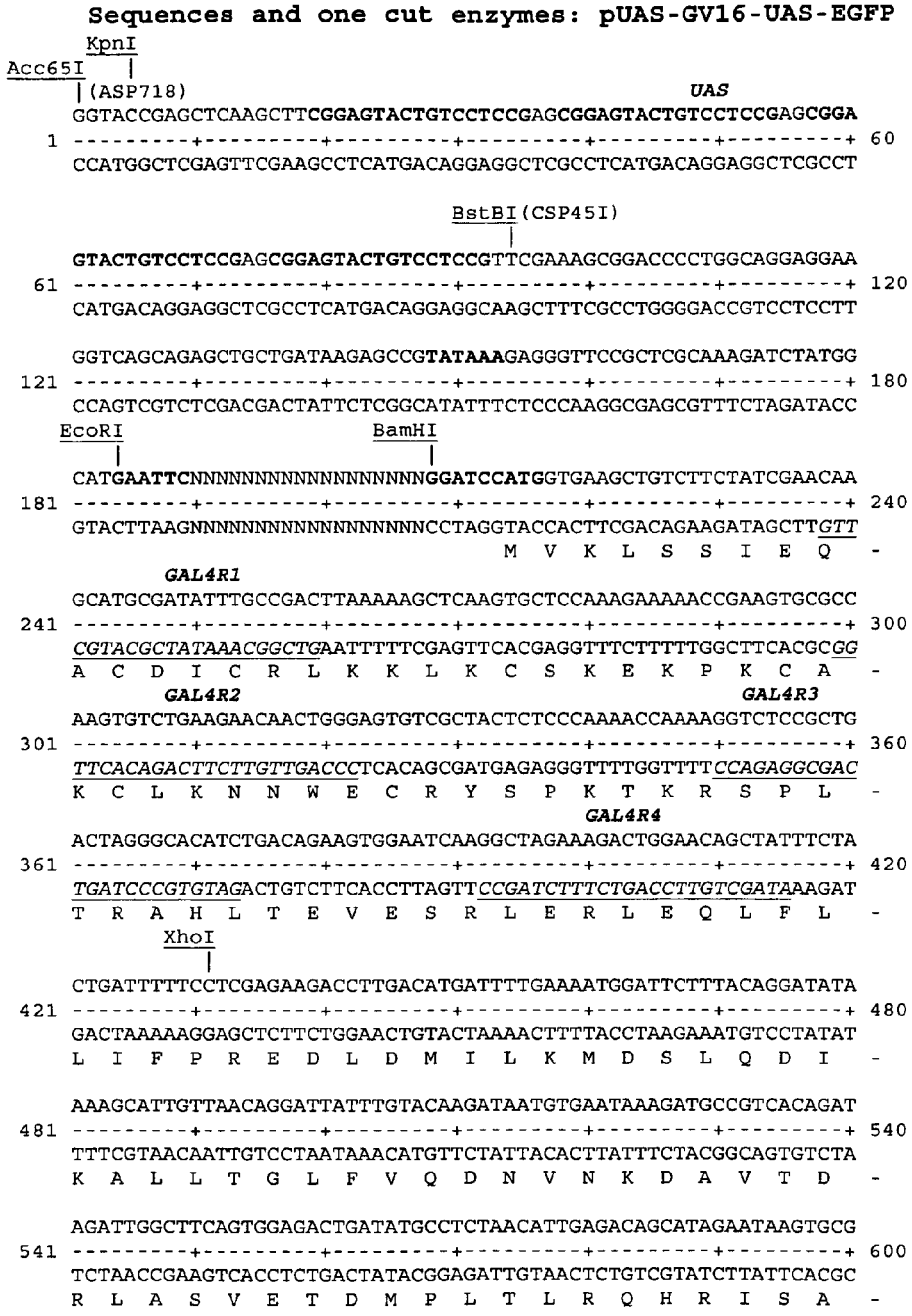

Sequences and one cut enzymes: pUAS-GV16-UAS-EGFP
KpnI
Acc65I
(ASP718)
UAS
GGTACCGAGCTCAAGCTTCGGAGTACTGTCCTCCGAGCGGAGTACTGTCCTCCGAGCGGA
CCATGGCTCGAGTTCGAAGCCTCATGACAGGAGGCTCGCCTCATGACAGGAGGCTCGCCT
BstBI(CSP45I)
GTACTGTCCTCCGAGCGGAGTACTGTCCTCCGTTCGAAAGCGGACCCCTGGCAGGAGGAA
CATGACAGGAGGCTCGCCTCATGACAGGAGGCAAGCTTTCGCCTGGGGACCGTCCTCCTT
GGTCAGCAGAGCTGCTGATAAGAGCCGTATAAAGAGGGTTCCGCTCGCAAAGATCTATGG
CCAGTCGTCTCGACGACTATTCTCGGCATATTTCTCCCAAGGCGAGCGTTTCTAGATACC
EcoRI
BamHI
CATGAATTCNNNNNNNNNNNNNNNNNGGATCCATGGTGAAGCTGTCTTCTATCGAACAA
GTACTTAAGNNNNNNNNNNNNNNNNNCCTAGGTACCACTTCGACAGAAGATAGCTTGTT
M V K L S S I E Q -
GAL4R1
GCATGCGATATTTGCCGACTTAAAAAGCTCAAGTGCTCCAAAGAAAAACCGAAGTGCGCC
CGTACGCTATAAACGGCTGAATTTTTCGAGTTCACGAGGTTTCTTTTTGGCTTCACGCGG
A C D I C R L K K L K C S K E K P K C A -
GAL4R2
GAL4R3
AAGTGTCTGAAGAACAACTGGGAGTGTCGCTACTCTCCCAAAACCAAAAGGTCTCCGCTG
TTCACAGACTTCTTGTTGACCCTCACAGCGATGAGAGGGTTTTGGTTTTCCAGAGGCGAC
K C L K N N W E C R Y S P K T K R S P L -
GAL4R4
ACTAGGGCACATCTGACAGAAGTGGAATCAAGGCTAGAAAGACTGGAACAGCTATTTCTA
TGATCCCGTGTAGACTGTCTTCACCTTAGTTCCGATCTTTCTGACCTTGTCGATAAAGAT
T R A H L T E V E S R L E R L E Q L F L -
XhoI
CTGATTTTTCCTCGAGAAGACCTTGACATGATTTTGAAAATGGATTCTTTACAGGATATA
GACTAAAAAGGAGCTCTTCTGGAACTGTACTAAAACTTTTACCTAAGAAATGTCCTATAT
L I F P R E D L D M I L K M D S L Q D I -
AAAGCATTGTTAACAGGATTATTTGTACAAGATAATGTGAATAAAGATGCCGTCACAGAT
TTTCGTAACAATTGTCCTAATAAACATGTTCTATTACACTTATTTCTACGGCAGTGTCTA
K A L L T G L F V Q D N V N K D A V T D -
AGATTGGCTTCAGTGGAGACTGATATGCCTCTAACATTGAGACAGCATAGAATAAGTGCG
TCTAACCGAAGTCACCTCTGACTATACGGAGATTGTAACTCTGTCGTATCTTATTCACGC
R L A S V E T D M P L T L R Q H R I S A -

Figure 4

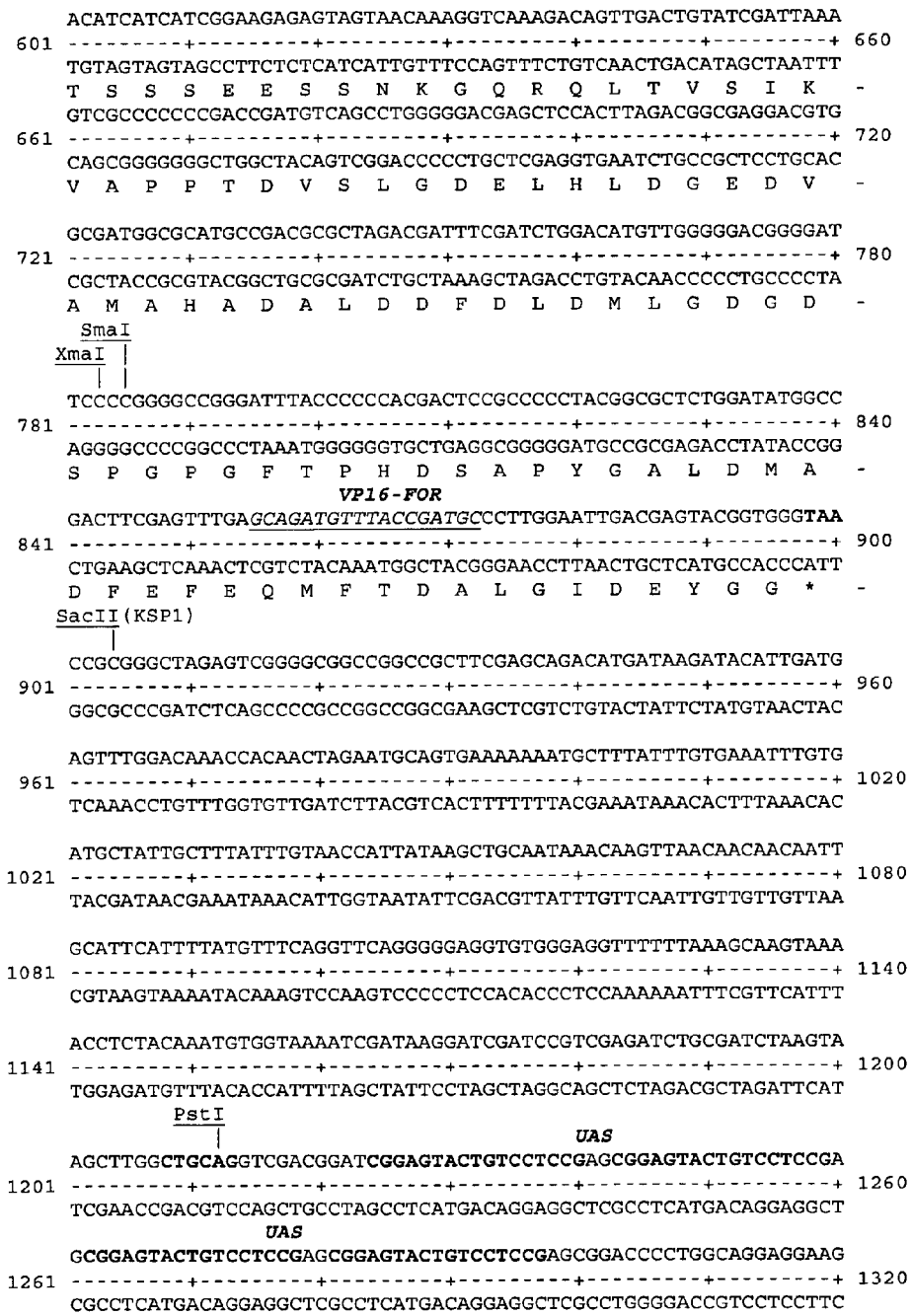
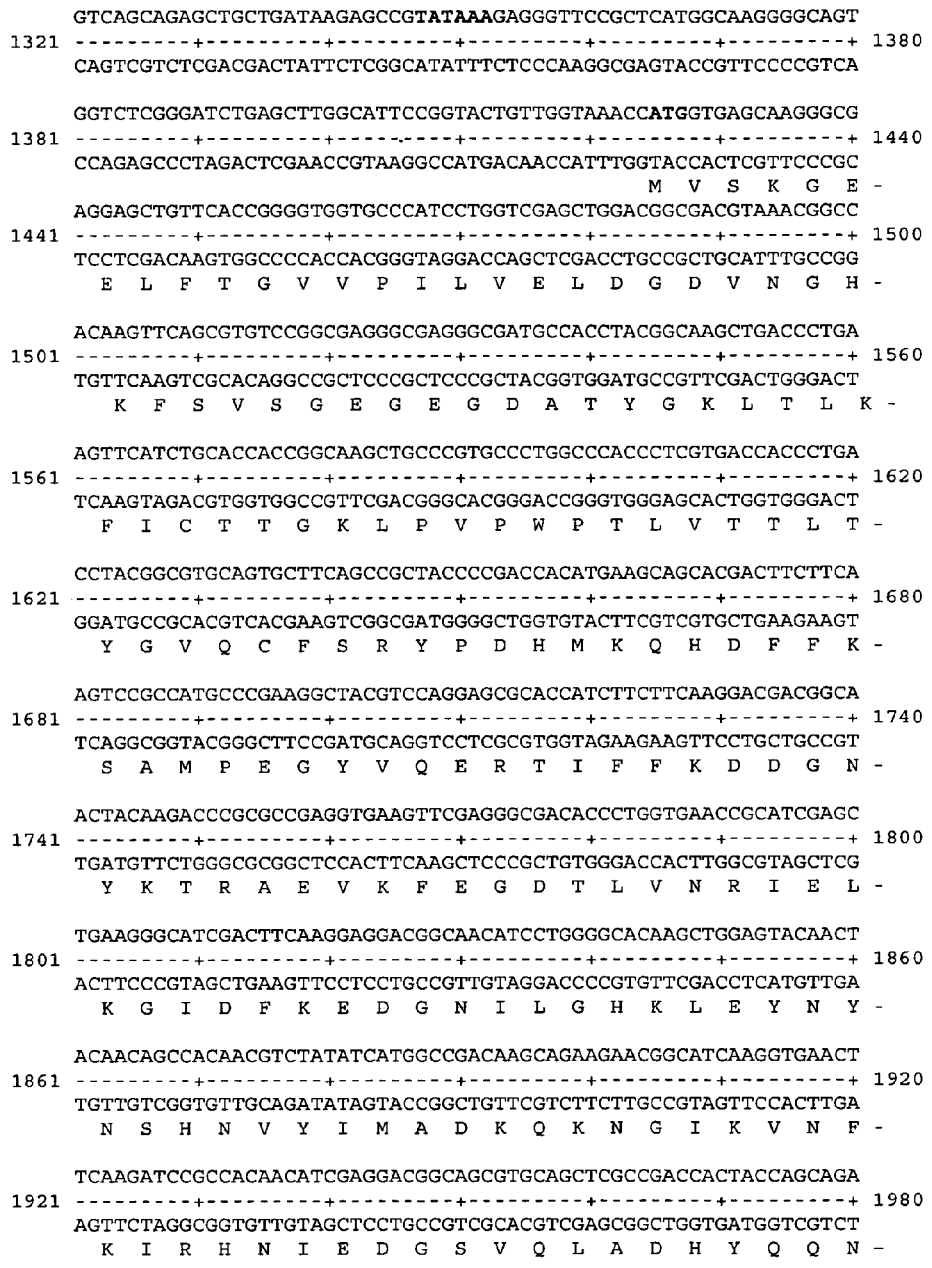


Figure 4 (cont'd)



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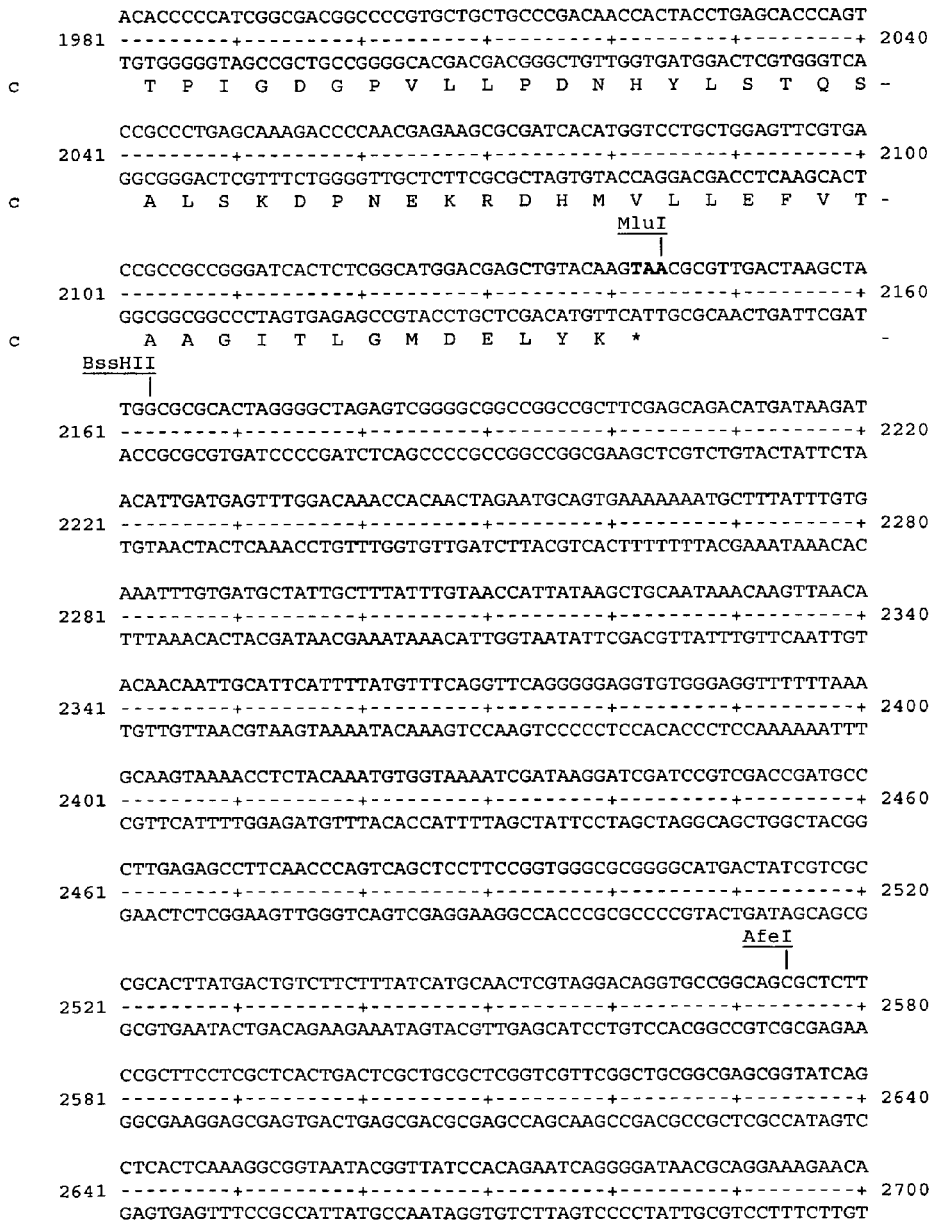

Figure 4 (cont'd)

```
     TGTGAGCAAAAGGCCAGCAAAAGGCCAGGAACCGTAAAAAGGCCGCGTTGCTGGCGTTTT
2701 ---------+---------+---------+---------+---------+---------+ 2760
     ACACTCGTTTTCCGGTCGTTTTCCGGTCCTTGGCATTTTTCCGGCGCAACGACCGCAAAA

     TCCATAGGCTCCGCCCCCCTGACGAGCATCACAAAAATCGACGCTCAAGTCAGAGGTGGC
2761 ---------+---------+---------+---------+---------+---------+ 2820
     AGGTATCCGAGGCGGGGGGACTGCTCGTAGTGTTTTTAGCTGCGAGTTCAGTCTCCACCG

     GAAACCCGACAGGACTATAAAGATACCAGGCGTTTCCCCCTGGAAGCTCCCTCGTGCGCT
2821 ---------+---------+---------+---------+---------+---------+ 2880
     CTTTGGGCTGTCCTGATATTTCTATGGTCCGCAAAGGGGGACCTTCGAGGGAGCACGCGA

     CTCCTGTTCCGACCCTGCCGCTTACCGGATACCTGTCCGCCTTTCTCCCTTCGGGAAGCG
2881 ---------+---------+---------+---------+---------+---------+ 2940
     GAGGACAAGGCTGGGACGGCGAATGGCCTATGGACAGGCGGAAAGAGGGAAGCCCTTCGC

     TGGCGCTTTCTCATAGCTCACGCTGTAGGTATCTCAGTTCGGTGTAGGTCGTTCGCTCCA
2941 ---------+---------+---------+---------+---------+---------+ 3000
     ACCGCGAAAGAGTATCGAGTGCGACATCCATAGAGTCAAGCCACATCCAGCAAGCGAGGT

     AGCTGGGCTGTGTGCACGAACCCCCCGTTCAGCCCGACCGCTGCGCCTTATCCGGTAACT
3001 ---------+---------+---------+---------+---------+---------+ 3060
     TCGACCCGACACACGTGCTTGGGGGGCAAGTCGGGCTGGCGACGCGGAATAGGCCATTGA

     ATCGTCTTGAGTCCAACCCGGTAAGACACGACTTATCGCCACTGGCAGCAGCCACTGGTA
3061 ---------+---------+---------+---------+---------+---------+ 3120
     TAGCAGAACTCAGGTTGGGCCATTCTGTGCTGAATAGCGGTGACCGTCGTCGGTGACCAT

     ACAGGATTAGCAGAGCGAGGTATGTAGGCGGTGCTACAGAGTTCTTGAAGTGGTGGCCTA
3121 ---------+---------+---------+---------+---------+---------+ 3180
     TGTCCTAATCGTCTCGCTCCATACATCCGCCACGATGTCTCAAGAACTTCACCACCGGAT

     ACTACGGCTACACTAGAAGAACAGTATTTGGTATCTGCGCTCTGCTGAAGCCAGTTACCT
3181 ---------+---------+---------+---------+---------+---------+ 3240
     TGATGCCGATGTGATCTTCTTGTCATAAACCATAGACGCGAGACGACTTCGGTCAATGGA

     TCGGAAAAAGAGTTGGTAGCTCTTGATCCGGCAAACAAACCACCGCTGGTAGCGGTGGTT
3241 ---------+---------+---------+---------+---------+---------+ 3300
     AGCCTTTTTCTCAACCATCGAGAACTAGGCCGTTTGTTTGGTGGCGACCATCGCCACCAA

     TTTTTGTTTGCAAGCAGCAGATTACGCGCAGAAAAAAAGGATCTCAAGAAGATCCTTTGA
3301 ---------+---------+---------+---------+---------+---------+ 3360
     AAAAACAAACGTTCGTCGTCTAATGCGCGTCTTTTTTTCCTAGAGTTCTTCTAGGAAACT

     TCTTTTCTACGGGGTCTGACGCTCAGTGGAACGAAAACTCACGTTAAGGGATTTTGGTCA
3361 ---------+---------+---------+---------+---------+---------+ 3420
     AGAAAAGATGCCCCAGACTGCGAGTCACCTTGCTTTTGAGTGCAATTCCCTAAAACCAGT

     TGAGATTATCAAAAAGGATCTTCACCTAGATCCTTTTAAATTAAAAATGAAGTTTTAAAT
3421 ---------+---------+---------+---------+---------+---------+ 3480
     ACTCTAATAGTTTTTCCTAGAAGTGGATCTAGGAAAATTTAATTTTTACTTCAAAATTTA
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Figure 4 (cont'd)

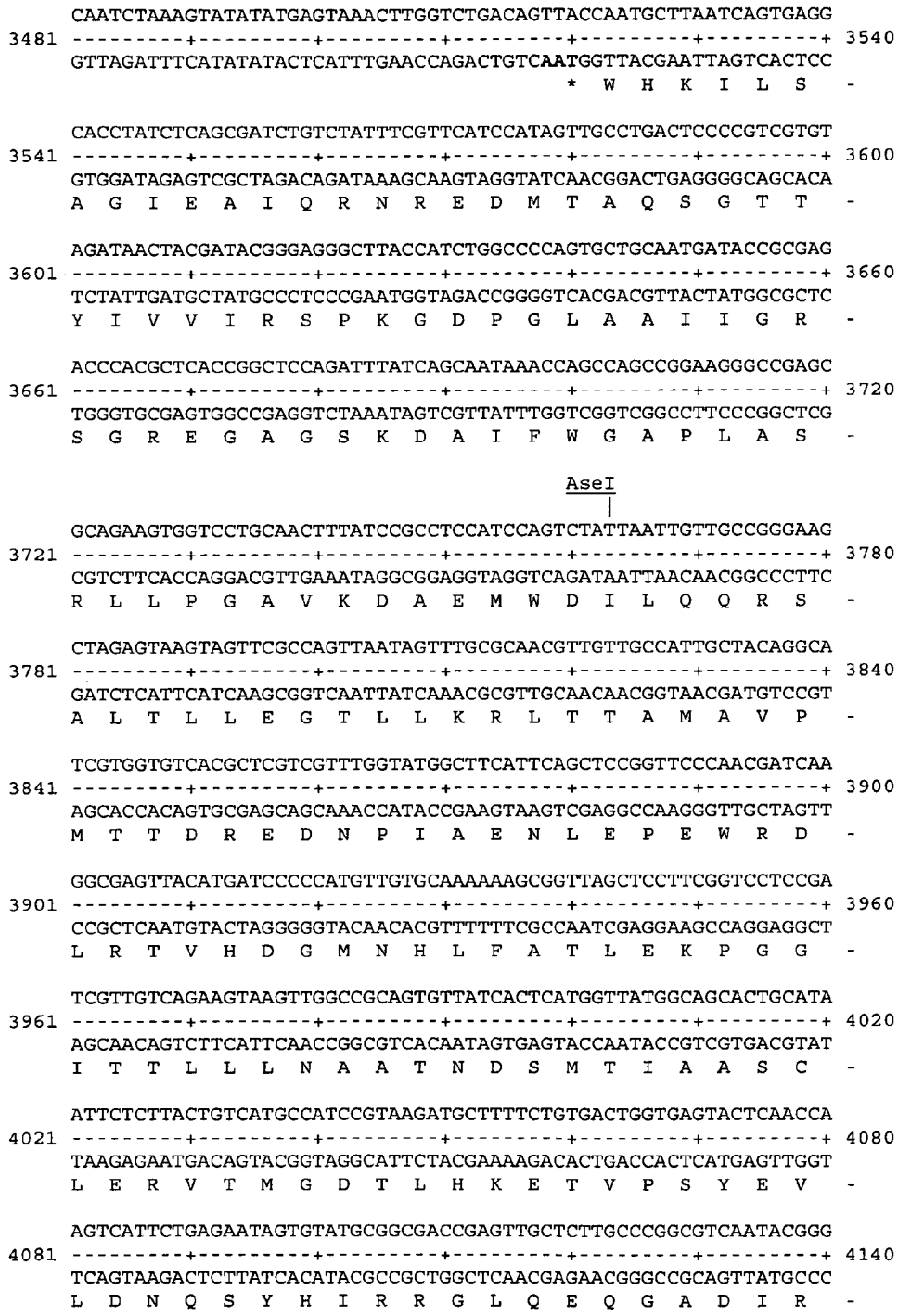

Figure 4 (cont'd)

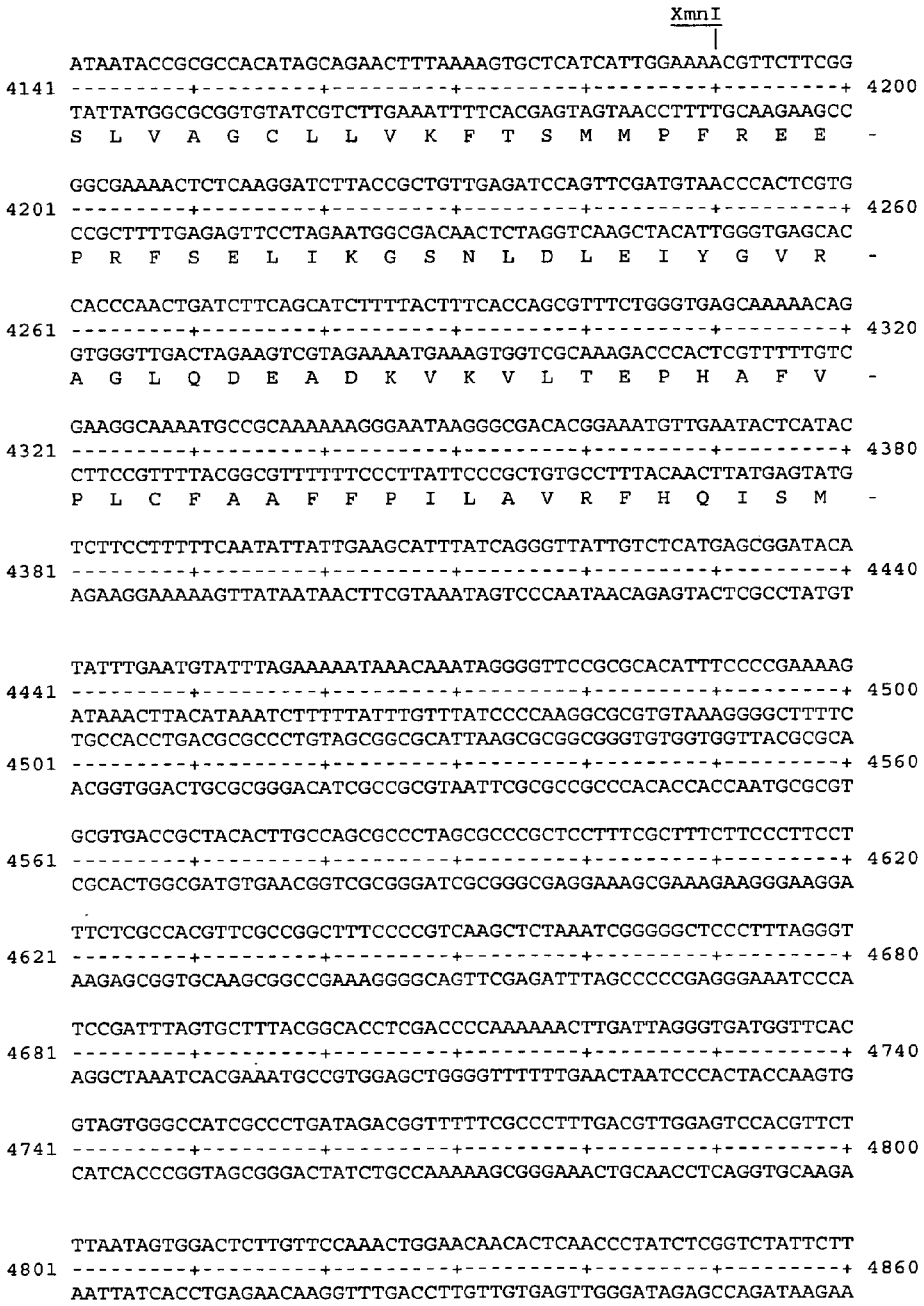

Figure 4 (cont'd)

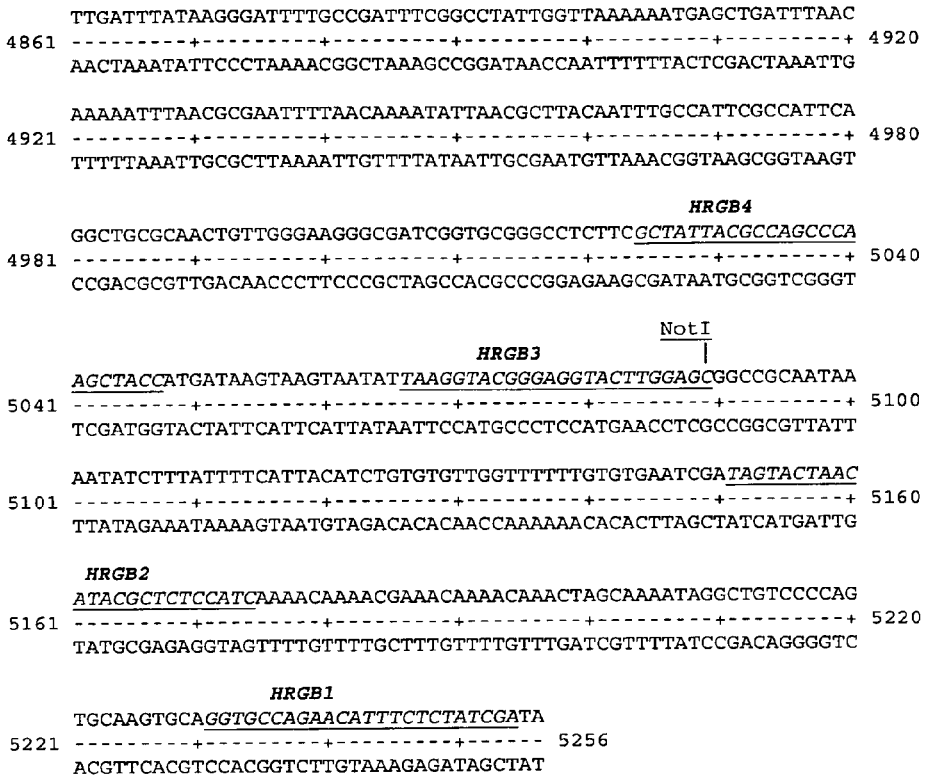

Figure 4 (cont'd)

Enzymes that do cut and were not excluded:

AarI	Acc65I	AfeI	AhdI	AloI	AlwNI	AseI	BamHI
BmgBI	BsaAI	BsaHI	BsaXI	BseRI	BseYI	BssHII	BstBI
BstEII	DraIII	EcoRI	FalI	KpnI	MluI	NotI	PfoI
PstI	SacII	SapI	SmaI	XhoI	XmaI	XmnI	

Enzymes that do not cut:

AatII	AflII	AgeI	AlfI	ApaI	AscI	AsiSI	AvrII
BaeI	BbeI	BbvCI	BclI	BfrBI	BlpI	BmtI	BplI
BsiWI	BsmBI	BspEI	BstAPI	BstXI	BstZ17I	Bsu36I	CspCI
EcoNI	Eco0109I	EcoRV	FspAI	KasI	MscI	NarI	NdeI
NheI	NruI	NsiI	PacI	PasI	PflMI	PmeI	PmlI
PpuMI	PspOMI	PspXI	PsrI	PvuII	RsrII	SanDI	SbfI
SexAI	SfiI	SfoI	SgrAI	SnaBI	SpeI	SrfI	StuI
SwaI	Tth111I	XbaI	XcmI	ZraI			

Enzymes excluded; MinCuts: 1 MaxCuts: 1

AccI	AclI	AcuI	AflIII	AleI	AloI	ApaLI	ApoI
AvaI	BanI	BanII	BbsI	BcgI	BcgI	BciVI	BglI
BglII	Bme1580I	BmrI	BpmI	Bpu10I	BpuEI	BsaI	BsaBI
BsaWI	BsaXI	BsgI	BsiEI	BsiHKAI	BsmI	Bsp1286I	BspHI
BspMI	BsrBI	BsrDI	BsrFI	BsrGI	BssSI	BstYI	BtgI
BtgZI	BtsI	ClaI	DraI	DrdI	EaeI	EagI	EarI
EciI	EcoICRI	Eco57MI	FseI	FspI	HaeII	Hin4I	Hin4I
HincII	HindIII	HpaI	MfeI	MmeI	MslI	MspA1I	NaeI
NcoI	NgoMIV	NspI	PciI	PpiI	PpiI	PshAI	PsiI
PvuI	SacI	SalI	ScaI	SfcI	SmlI	SphI	SspI
StyI	TaqII	TaqII	TatI				

Figure 5

TRANSLATION ENHANCER-ELEMENT DEPENDENT VECTOR SYSTEMS

CROSS REFERENCE TO RELATED APPLICATION(S)

This application claims the benefit of priority under 35 U.S.C. §119(e) of U.S. Ser. No. 60/711,149, filed Aug. 24, 2005, the entire content of which is incorporated herein by reference.

INCORPORATION BY REFERENCE OF SEQUENCE LISTING

The contents of the text file named "PROO-007001US_Sequence_Listing_ST25.txt," which was created on May 13, 2015 and is 20 KB in size, are hereby incorporated by reference in their entirety.

GRANT INFORMATION

This invention was made with support from NIH Grant No. GM 61725. The government has certain rights in this invention.

FIELD OF INVENTION

The present invention relates generally to vector constructs, and more specifically to positive feedback vector constructs bearing translational enhancer elements (TEEs) in combination with transcriptional elements and genes encoding transcription factors, where such constructs may be used to identify other TEEs and to modulate levels of protein expression.

BACKGROUND OF THE INVENTION

Eukaryotic mRNAs can initiate translation by either cap-dependent or cap-independent mechanisms. Presently, the relative contributions of these mechanisms to the proteome are unknown; however, some studies suggest that cap-independent mechanisms may account for the translation of many mRNAs. For some mRNAs, cap-independent translation is facilitated by sequence elements termed internal ribosome entry sites (IRESes). IRESes were first discovered in uncapped picornavirus RNAs and were subsequently identified in other viral and cellular mRNAs from mammals, insects, and yeast. For some mRNAs, IRESes facilitate translation when cap-dependent initiation is less efficient or blocked. Internal initiation also facilitates the translation of particular mRNAs with 5' leaders that are encumbered by numerous upstream AUGs or RNA secondary structures.

A variety of evidence suggests that different IRESes vary in length, sequence composition, and in their requirements for initiation factors or other trans-acting factors, suggesting that internal initiation of translation occurs by a number of different mechanisms. Some IRESes are modular in composition. For example, an IRES module from the 5' leader of the Gtx homeodomain mRNA showed that maximal activity was obtained with sequences of 7 nucleotides. Various lines of evidence suggested that the mechanism underlying the activity of this sequence element involves base pairing to a complementary sequence of 18S rRNA. In another study, a 22-nt IRES was identified in the 5' leader of the Rbm3 mRNA. In addition, it has been reported that the 5' leader of the thymidine kinase mRNA contains an IRES-element and that the 5' leader of the c-myc mRNA contains two short IRES elements.

The short size of some IRES/TEE modules suggests that they may be prevalent within mRNA populations.

Some IRES elements can also function as translation enhancer elements (TEEs), i.e., they can enhance translation in the context of a monocistronic mRNA. However, not all TEEs are IRESes and not all IRESes are TEEs.

SUMMARY OF THE INVENTION

The present invention describes a series of vectors designed to select for translational enhancer elements and overexpression of proteins of interest, and includes methods for the use of such vectors.

In one embodiment, a nucleic acid vector including a first construct that includes two or more first transcriptional elements, a first cistron encoding a transcription factor, and one or more first translational enhancer elements (TEEs), where the transcription factor amplifies the transcription of at least one cistron of the first construct is envisaged.

In a related aspect, the vector may include, but is not limited to, at least one cistron on one or more second constructs including at least one transcriptional unit. In a further related aspect, the first construct and the at least one transcriptional unit of one or more second constructs include transcriptional elements that are targets for the transcription factor encoded by the first cistron.

In a related aspect, such vectors may encode a gene product that is a reporter protein, a therapeutic protein, an enzyme, an antigen, a structural protein, or an antibody.

In another aspect, at least one gene product blocks host protein synthesis. In a related aspect, the gene product may include, but is not limited to, NSP3, L-proteinase, or proteinase 2A.

In one aspect, the vector includes at least one TEE that is resistant to the activity of the product which blocks host protein synthesis, where the vector may contain transcriptional elements including, but not limited to, minimal promoters, regulatable promoters, upstream activating sequences, and bacteriophage RNA polymerase specific promoters.

In another embodiment, a nucleic acid vector including a first construct which includes a first transcriptional element, a first cistron encoding a first gene product, and a first translational enhancer element (TEE), wherein the TEE is resistant to an activity of a second gene product which blocks host protein synthesis is envisaged.

In a related aspect, TEEs include, HCV-IRES, IRESes, and IRES-elements, including, but not limited to, Gtx sequences (e.g., Gtx9-nt, Gtx8-nt, Gtx7-nt). In another related aspect, TEEs may include N-18 random nucleotides which when operably linked to a cistron, increase the amount of protein induced per unit mRNA.

In one embodiment, a method of identifying a translational enhancer element (TEE) is envisaged including inserting nucleotides from a library of nucleotides into a vector including a first construct which includes two or more first transcriptional elements, and a first cistron encoding a transcription factor, transfecting a cell with the vector, and determining the level of gene product translation from one or more second constructs in the transfected cell, where determining an enhanced level of translation of the gene product in the presence of the inserted nucleotides is indicative of the presence of at least one TEE.

In a related aspect, the method may further include co-transfecting the cell with one or more second vectors, wherein the second vectors include the one or more second constructs.

In another embodiment, a method of overexpressing a gene is envisaged including, transfecting a cell with a vector including a first construct including two or more first transcriptional elements, a first cistron encoding a transcription factor, and one or more first translation enhancer elements (TEEs), and expressing a gene product from one or more second constructs including a second TEE, where the resulting level of gene product expressed from the second construct is enhanced in the presence of the first and second TEEs.

In a related aspect, the method may further include co-transfecting the cell with one or more second vectors including the one or more second constructs. In a further related aspect, the method may further include expressing a gene from a third construct including a third TEE, where the gene from the third construct encodes one or more gene products which block host protein synthesis. In a related aspect, the method may further include co-transfecting the cell with a third vector including the third construct.

In one embodiment, a method of overexpressing a gene is envisaged including transfecting a cell with a vector including a first construct including at least one first transcriptional element, a first cistron encoding a first gene product, and at least one translational enhancer element (TEE) and expressing a gene from one or more second constructs encoding a protein which blocks host protein synthesis, where the resulting level of gene product expressed from the first construct is enhanced in the presence of the blocking protein.

Exemplary methods and compositions according to this invention, are described in greater detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a translation enhancer-driven positive feedback vector. A schematic representation of the positive feedback vector is shown along with the various promoter (P1) and transcriptional enhancer (P2) sequences, transcription factor (TF) genes, and a protein of interest. The transcription factor gene and the gene of interest may be on the same plasmid or on different plasmids. For the selection application, a random nucleotide sequence (N), n nucleotides in length is present in the 5' leader of the transcription factor mRNA. A sequence that functions as a translational enhancer element (TEE) will facilitate the translation of this mRNA. The encoded transcription factor will then bind to sites in the promoters of the two genes and increase their transcription.

FIG. **2** illustrates a translation enhancer-driven positive feedback vector with a third protein to block host protein synthesis. The first two genes (transcription factor gene and gene of interest) are the same as in FIG. **1** except that all three mRNAs contain a TEE in their 5' leader. The third protein (e.g., the Rotavirus NSP3 protein) will increase the translation of the first two encoded mRNAs by blocking the translation of host mRNAs and reducing the competition from them. The third gene is under the transcriptional control of promoter P3, which is either a constitutive promoter or an inducible promoter. P3 may also include promoter elements P1 and P2. For the selection application, the mRNAs for the gene of interest and third protein will contain a known TEE, while the transcription factor gene will contain a random nucleotide sequence. In this scenario, the TEE is resistant to the activity of the third protein. For a protein production application, all three genes may contain a known TEE that is resistant to the activity of the third protein. The three genes may be on one, two, or three different plasmids.

FIG. **3** illustrates a protein overexpression vector. The first gene encodes the gene of interest. As shown in FIG. **2**, each gene contains a TEE in its 5' leader. In this scenario, the TEE is resistant to the activity of the other encoded protein (e.g., NSP3). The two genes may be on one or two different plasmids.

FIG. **4** shows a restriction map for a positive feedback reporting vector (SEQ ID NO: 1). Sequences in bold represent: 1) promoter sequences, including TATA boxes and upstream activating sequences (UAS); 2) GAL4R1-GAL4R4, primer sequences for PCR amplification; 3) ATG and TAA, start and stop translation sequences, respectively; and 4) HRGB1-HRGB4, primer sequences for PCR amplification.

FIG. **5** shows one-cut enzymes for pUAS-GV16-UAS-EGFP (SEQ ID NO: 1).

DETAILED DESCRIPTION OF THE INVENTION

Before the present compositions and methods are described, it is understood that this invention is not limited to the particular methodology, protocols, and reagents described as these may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention which will be described by the appended claims.

It must be noted that as used herein and in the appended claims, the singular forms "a", "an", and "the" include plural reference unless the context clearly dictates otherwise. Thus, for example, reference to "a cell" includes a plurality of such cells, reference to "a protein" includes one or more proteins and equivalents thereof known to those skilled in the art, and so forth.

Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the methods, devices, and materials are now described. All publications mentioned herein are incorporated herein by reference for the purpose of describing and disclosing the proteins, nucleic acids, and methodologies which are reported in the publications which might be used in connection with the invention. Nothing herein is to be construed as an admission that the invention is not entitled to antedate such disclosure by virtue of prior invention.

As used herein, "translational enhancer element (TEE)," including grammatical variations thereof, means cis-acting sequences that increase the amount of protein induced per unit mRNA. In a related aspect, TEEs include, HCV-IRES, IRESes, and IRES-elements, including, but not limited to, Gtx sequences (e.g., Gtx9-nt, Gtx8-nt, Gtx7-nt). In another related aspect, TEEs may include N-18 random nucleotides which when operably linked to a cistron, increase the amount of protein induced per unit mRNA.

In a further related aspect, sequences for such elements include, but are not limited to, GenBank accession numbers AX205123 and AX205116 (Gtx IRES element), D17763 (HCV-IRES, 5'-untranslated region).

As used herein, "cistron" including grammatical variations thereof, means a unit of DNA that codes for a single polypeptide or protein.

As used herein, "transcriptional unit," including grammatical variations thereof, means the segment of DNA within which the synthesis of RNA occurs.

As used herein, "nucleotide sequence," "nucleic acid sequence," "nucleic acid," or "polynucleotide," refers to a deoxyribonucleotide or ribonucleotide polymer in either single- or double-stranded form, and unless otherwise limited, encompasses known analogs of natural nucleotides that hybridize to nucleic acids in a manner similar to naturally-occurring nucleotides. Nucleic acid sequences can be, e.g., prokaryotic sequences, eukaryotic mRNA sequences, cDNA sequences from eukaryotic mRNA, genomic DNA sequences from eukaryotic DNA (e.g., mammalian DNA), and synthetic DNA or RNA sequences, but are not limited thereto.

In a related aspect, synthetic methods for preparing a nucleotide sequence include, for example, the phosphotriester and phosphodiester methods (see Narang et al., Meth. Enzymol. 68:90, (1979); U.S. Pat. No. 4,356,270, U.S. Pat. No. 4,458,066, U.S. Pat. No. 4,416,988, U.S. Pat. No. 4,293,652; and Brown et al., Meth Enzymol 68:109, (1979), each of which is incorporated herein by reference).

As used herein, "promoter" including grammatical variations thereof, means a nucleic acid sequence capable of directing transcription. A variety of promoter sequences are known in the art. For example, such elements can include, but are not limited to, TATA-boxes, CCAAT-boxes, bacteriophage RNA polymerase specific promoters (T7: TAATACGACTCACTATAGG (SEQ ID NO: 4); SP6: ATTTAGGTGACACTATAGA (SEQ ID NO: 5); and T3: AATTAACCCTCACTAAAGG (SEQ ID NO: 6)), an SP1 site (GGGCGG), and a cyclic AMP response element (TGACGTCA).

As used herein, "transcriptional element," including grammatical variations thereof, means a cis-acting site on DNA that allows for initiation or stimulation of initiation of transcription, usually through recognition by a transcription factor. For example, such elements exist in motifs including, but not limited to, CACGTG (c-Myc), TGAc/gTc/aA (c-Fos), and t/aGATA (GATA). In a related aspect, the vector may contain one or more transcriptional elements comprising one or more upstream activating sequences (UAS), including but not limited to, the consensus GAGTACTGTCCTCCGAGCG (SEQ ID NO: 7).

As used herein, "transcription factor," including grammatical variations thereof, means any protein required to initiate or regulate transcription. For example, such factors include, but are not limited to, c-Myc, c-Fos, c-Jun, CREB, cEts, GATA, GAL4, GAL4/Vp16, c-Myb, MyoD, NF-κB, bacteriophage-specific RNA polymerases, Hif-1, and TRE.

In a further related aspect, sequences for such factors include, but are not limited to, GenBank accession numbers K02276 (c-Myc), K00650 (c-fos), BC002981 (c-jun), M27691 (CREB), X14798 (cEts), M77810 (GATA), K01486 (GAL4), AY136632 (GAL4/Vp16), M95584 (c-Myb), M84918 (MyoD), 2006293A (NF-κB), NP 853568 (SP6 RNA polymerase), AAB28111 (T7 RNA polymerase), NP 523301 (T3 RNA polymerase), AF364604 (HIF-1), and X63547 (TRE).

As used herein, "transcriptional activator regions," including grammatical variations thereof, means protein sequences that, when tethered to DNA near a promoter, activate transcription by contacting targets in the transcriptional machinery (see, e.g., Xiangyang et al., Proc Natl Acad Sci USA (2000) 97:1988-1992). Activator regions, characterized by having an excess of acidic amino acid residues, are found in a wide array of eukaryotic activators, including the yeast activators Gal4, GCN4, and the herpesvirus activator VP16.

As used herein, "construct," including grammatical variations thereof, means nucleic acid sequence elements arranged in a definite pattern of organization such that the expression of genes/gene products that are operably linked to these elements can be predictably controlled. In a related aspect, a wide variety of heterologous sequences may be included in the construct, including, but not limited to, for example, sequences which encode growth factors, cytokines, chemokines, lymphokines, toxins, prodrugs, antibodies, antigens, ribozymes, as well as antisense sequences. In another related aspect, such heterologous sequences encode proteins which can serve as therapeutic modalities.

As used herein, "vector," including grammatical variations thereof, means the DNA of any transmissible agent (e.g., plasmid or virus) into which a segment of foreign DNA can be spliced in order to introduce the foreign DNA into host cells to promote its replication and/or transcription.

As disclosed herein, a vector comprising a construct is useful for identifying translational enhancer elements. In one embodiment, the construct is contained in a vector, which generally is an expression vector that contains certain components, but otherwise can vary widely in sequence and in functional element content. The vector also can contain sequences that facilitate recombinant DNA manipulations, including, for example, elements that allow propagation of the vector in a particular host cell (e.g., a bacterial cell, insect cell, yeast cell, or mammalian cell), selection of cells containing the vector (e.g., antibiotic resistance genes for selection in bacterial or mammalian cells), and cloning sites for introduction of reporter genes or the elements to be examined (e.g., restriction endonuclease sites or recombinase recognition sites).

Preferably, constructs as envisaged provide the advantage that the activity of an oligonucleotide can be examined in the context or milieu of the whole eukaryotic chromosome. A chromosome offers unique and complex regulatory features with respect to the control of gene expression, including translation. As such, it is advantageous to have a system and method for obtaining regulatory oligonucleotides that function in the context of a chromosome. Thus, a method of the invention can be practiced such that integration of the expression vector into the eukaryotic host cell chromosome occurs, forming a stable construct prior to selection for an expressed reporter molecule.

A vector comprising a construct as envisaged can be integrated into a chromosome by a variety of methods and under a variety of conditions. Thus, the present invention should not be construed as limited to the exemplified methods. Shotgun transfection, for example, can result in stable integration if selection pressure is maintained upon the transfected cell through several generations of cell division, during which time the transfected nucleic acid construct becomes stably integrated into the cell genome. Directional vectors, which can integrate into a host cell chromosome and form a stable integrant, also can be used. These vectors can be based on targeted homologous recombination, which restricts the site of integration to regions of the chromosome having the homology, and can be based on viral vectors, which can randomly associate with the chromosome and form a stable integrant, or can utilize site specific recombination methods and reagents such as a lox-Cre system and the like.

Shotgun transfections can be accomplished by a variety of well known methods, including, for example, electroporation, calcium phosphate mediated transfection, DEAE dextran mediated transfection, a biolistic method, a lipofectin method, and the like. For random shotgun transfections, the culture conditions are maintained for several generations of cell division to ensure that a stable integration has resulted and, generally, a selective pressure also is applied. A viral vector based integration method also can be used and pro-

vides the advantage that the method is more rapid and establishes a stable integration by the first generation of cell division. A viral vector based integration also provides the advantage that the transfection (infection) can be performed at a low vector:cell ratio, which increases the probability of single copy transfection of the cell. A single copy expression vector in the cell during selection increases the reliability that an observed regulatory activity is due to a particular oligonucleotide, and facilitates isolation of such an oligonucleotides.

Reference is made herein to techniques commonly known in the art. Guidance in the application of such techniques can be found, e.g., in Ausubel et al. eds., 1995, Current Protocols In Molecular Biology, and in Sambrook et al., 1989, Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, NY, the contents of which are incorporated herein by reference.

Previous studies have generated synthetic IRESes containing multiple individual IRES elements and showed that this multimerization led to higher, and in some cases exponential, increases in IRES activity. To facilitate the discovery process, a number of methods to screen for IRES elements in mammalian cells and in yeast have been developed. In all of these methods, dicistronic mRNAs containing a library of random nucleotide sequences in the intercistronic sequences (ICS) were expressed in cells, and those cells containing IRES elements were identified on the basis of the expression of the second cistron. The mammalian methods used a fluorescent reporter protein as the second cistron, and positive cells were identified with FACS. However, a limitation of these methods was that the activities of individual IRES elements were relatively low, leading to a large number of false positive cells.

To circumvent this signal-to-noise problem, the present invention describes a positive feedback based system where one cistron encoding a TEE containing transcription factor triggers a positive feedback loop in which the transcription factor binds to a select sequence in the upstream promoter of the cistron encoding the factor and one or more cistrons encoding an mRNA of interest, thereby increasing the transcription of both mRNAs. More mRNA results in more transcription factor, leading to ever-increasing amounts of both the transcription factor and protein of interest mRNA and the encoded proteins.

In one embodiment, the vector system is a translation enhancer-driven positive feedback vector (e.g., see FIG. **1**). In one aspect, a construct expresses two mRNAs: one encoding a protein of interest which may be a reporter protein and the other encoding a transcription factor. The transcription of both mRNAs is driven by minimal promoters but can be enhanced by the expression of the transcription factor via binding sites for the transcription factor that are located in the promoters of both genes. A small amount of transcription factor mRNA is expressed from the minimal promoter but the translation of this mRNA is blocked by an obstacle in the 5' leader of the mRNA encoding the transcription factor. This obstacle may be a stable stem-loop structure and/or upstream AUG initiation codons. The synthesis of this transcription factor is dependent on the presence of a translation enhancer in the mRNA encoding this factor.

The translational enhancer can be located in the 5' leader of the mRNA, downstream of the inhibitory elements but upstream of the initiation codon, or it may be located in the 3' untranslated region (UTR). In one aspect, the TEE is situated in the 5' leader sequence which is contained within a cistron.

Utilization of this vector system may require that the encoded transcription factor not be expressed in the cells of interest. For example, a transcription factor (e.g., Gal4/Vp16), that contains the DNA binding domain of the yeast GAL4 transcription factor is suitable for use in mammalian cells because mammalian genes do not appear to be targets of this transcription factor. Other suitable transcription factors include, but are not limited to, those that are expressed endogenously at very low levels, or are absent in the cells of interest. For example, bacteriophage specific-RNA polymerases (e.g., T7, T3, and SP6 RNA polymerases) are suitable for use in both mammalian cells and yeast. The genes as envisaged can be encoded by one or more vectors.

In one embodiment, the vector system can be used to identify a TEE. An oligonucleotide to be examined for translational activity can be operatively linked to an expressible polynucleotide, which, for example, can encode a reporter molecule. As used herein, the term "operatively linked" means that a regulatory element, which can be a synthetic regulatory oligonucleotide or an oligonucleotide to be examined for such activity, is positioned with respect to a translatable nucleotide sequence such that the regulatory element can affect its regulatory activity. An oligonucleotide having translational enhancer activity generally is positioned within about 1 to 500 nucleotides, particularly within about 1 to 100 nucleotides of a translation start site.

A library of randomized oligonucleotides to be examined for translational regulatory activity can be provided, and one or more individual members of the library can be cloned into multiple copies of the construct of the vector. The oligonucleotide to be examined for translational regulatory activity is introduced such that it is operatively linked to the minimal promoter element in the construct and, therefore, has the potential to function as a TEE. In this way, a library of different constructs, which can be contained in a vector, is formed, each construct differing in the introduced potential regulatory oligonucleotide sequence.

Oligonucleotides to be examined for translational regulatory activity can be, for example, cDNA sequences encoding 5' UTRs of cellular mRNAs, including a library of such cDNA molecules. Furthermore, as disclosed herein, TEEs identified according to a method of the invention, including synthetic TEE elements, have been found to be complementary to oligonucleotide sequences of ribosomal RNA, particularly to un-base paired oligonucleotide sequences of rRNA, which are interspersed among double stranded regions that form due to hybridization of self complementary sequences within rRNA. Accordingly, oligonucleotides to be examined for translational regulatory activity, can be designed based on their being complementary to an oligonucleotide sequence of rRNA, particularly to an un-base paired oligonucleotide sequence of rRNA such as a yeast, mouse or human rRNA (e.g., see GenBank Accession Nos. V01335, X00686, X03205, each of which is incorporated herein by reference). In addition, oligonucleotides to be examined for translational regulatory activity can be a library of variegated oligonucleotide sequences (see, for example, U.S. Pat. No. 5,837,500, incorporated herein by reference), which can be based, for example, on a translational enhancer element as disclosed herein or identified using a method of the invention, or on an oligonucleotide sequence complementary to an un-base paired region of a rRNA.

The oligonucleotides identified herein as having translational regulatory activity provide modules that can be used alone or combined with each other to produce desired activities. For example, concatemers of an identified TEE can vastly increase polypeptide expression from an associated cistron, including concatemers of 2, 5, 10, 20, 35, 50 or 75 copies of a TEE, which independently can be multiple copies of the same or different TEEs, and which can be operatively

linked adjacent to each other or separated by spacer nucleotide sequences that can vary from 1 to about 100 nucleotides in length.

A synthetic translational regulatory element can be identified by screening, for example, a library of oligonucleotides containing a large number of different nucleotide sequences. The oligonucleotides can be variegated oligonucleotide sequences, which are based on but different from a known translational regulatory element, for example, an oligonucleotide complementary to an un-base paired sequence of a rRNA, or can be a random oligonucleotide library. The use of randomized oligonucleotides (e.g., N18) provides the advantage that no prior knowledge is required of the nucleotide sequence, and provides the additional advantage that completely new regulatory elements can be identified. Methods for making a combinatorial library of nucleotide sequences or a variegated population of nucleotide sequences are well known in the art (see, for example, U.S. Pat. No. 5,837,500; U.S. Pat. No. 5,622,699; U.S. Pat. No. 5,206,347; Scott and Smith, Science 249:386-390, 1992; Markland et al., Gene 109:13 19, 1991; O'Connell et al., Proc Natl Acad Sci, USA 93:5883-5887, 1996; Tuerk and Gold, Science 249:505-510, 1990; Gold et al., Ann Rev Biochem 64:763-797, 1995; each of which is incorporated herein by reference).

A synthetic TEE oligonucleotide, which can be obtained using a method of the invention, can increase or decrease the level of translation of an mRNA containing the oligonucleotide. In particular, a TEE oligonucleotide can selectively regulate translation in a context specific manner, depending, for example, on the cell type for expression, the nature of the TEE sequence, or the presence of other effector sequences in the construct.

A regulatory element can be of various lengths from a few nucleotides to several hundred nucleotides. Thus, the length of an oligonucleotide in a library of oligonucleotides to be screened can be any length, including oligonucleotides as short as about 6 nucleotides or as long as about 100 nucleotides or more. Generally, the oligonucleotides to be examined are about 6, 12, 18, 30 nucleotides or the like in length. The complexity of the library, i.e., the number of unique members, also can vary, although preferably the library has a high complexity so as to increase the likelihood that regulatory sequences are present. Libraries can be made using any method known in the art, including, for example, using an oligonucleotide synthesizer and standard oligonucleotide synthetic chemistry. Where the oligonucleotides are to be incorporated into a vector, the library complexity depends in part on the size of the expression vector population being used to clone the random library and transfect cells. Thus, a theoretical limitation for the complexity of the library also relates to utilization of the library content by the recipient expression vector and by the transfected cells, as well as by the complexity that can be obtained using a particular method of oligonucleotide synthesis.

To identify TEEs, libraries of constructs that contain either random nucleotide sequences or cDNA segments of 5' leaders of mRNAs are introduced into cells. Cells containing a construct with a TEE upstream of the transcription factor will trigger the positive feedback mechanism and produce large amounts of both proteins. If one of the proteins is a reporter protein, its activity can be readily assayed. For example, if the reporter is enhanced green fluorescent protein (EGFP), fluorescence activated cell sorting (FACS) can be used to identify cells expressing the fluorescent protein. In a preferred embodiment of the present invention, the means of detecting the presence of GFP in transfected cells is by fluorescence microscopy and by FACS. However, it will be readily understood by those of skill in the art that other means for detecting the presence of GFP may also be used in the practice of the present invention. The means of detecting GFP or of tracking or monitoring cells which have been transfected with a construct of the present invention may be any means whereby the presence GFP protein is detectable. For example, optical imaging, infrared imaging of gene expression, and flow cytometry may also be used.

In a related aspect, other reporter proteins can include, but are not limited to, enhanced yellow fluorescent protein (EYFP), enhanced cyan fluorescent protein (ECFP), luciferase, β-galactosidase, β-glucuronidase, alkaline phosphatase, and chloramphenicol acetyltransferase.

In a related aspect, such a vector can be used to identify sequences that enhance translation by various mechanisms, including but not limited to, cap-independent and cap-dependent mechanisms.

In one aspect, the vector system as envisaged can be used to overexpress another protein of interest. In a related aspect, the mRNA encoding the transcription factor will contain a known TEE. Such a system may be suitable for the batch production of proteins, where the transcription factor is under the control of a regulatable promoter, so that cells can be grown to a large volume before the positive feed back mechanisms and large scale protein production are induced by, for example, an inducing agent.

The term "inducing agent" is used to refer to a chemical, biological or physical agent that effects translation from an inducible translational regulatory element. In response to exposure to an inducing agent, translation from the element generally is initiated de novo or is increased above a basal or constitutive level of expression. Such induction can be identified using the methods disclosed herein, including detecting an increased level of a reporter polypeptide encoded by the expressible polynucleotide that is operatively linked to the TEE. An inducing agent can be, for example, a stress condition to which a cell is exposed, for example, a heat or cold shock, a toxic agent such as a heavy metal ion, or a lack of a nutrient, hormone, growth factor, or the like; or can be exposure to a molecule that affects the growth or differentiation state of a cell such as a hormone or a growth factor. As disclosed herein, the translational regulatory activity of an oligonucleotide can be examined in cells that are exposed to particular conditions or agents, or in cells of a particular cell type, and oligonucleotides that have translational regulatory activity in response to and only under the specified conditions or in a specific cell type can be identified.

In another embodiment, a vector system is envisaged which expresses a third mRNA that encodes a protein that can increase the translation of the other two encoded mRNAs by decreasing the translation of cellular mRNAs (FIG. **2**). In one aspect, the expression of the third protein decreases competition from the cellular mRNAs and leads to an increased signal-to-noise ratio in the selection application.

In a related aspect, the third protein may be a viral protein that blocks translation of host mRNAs and thereby decreases the competition arising from these mRNAs. Viral proteins include, but are not limited to, NSP3, L-proteinase, or proteinase 2A. For example, without being bound to theory, the NSP3 protein blocks cap-dependent translation by binding to the eukaryotic initiation factor 4G (eIF4G) with high affinity, displacing the poly(A) binding protein, disrupting mRNA circulation, and dramatically decreasing efficiency. In this scenario, the three vector encoded mRNAs contain features that prevent their translation from being blocked. For example, where a TEE does not require eIF4G for activity, such an element would be resistant to NSP3 (e.g., Gtx IRES

elements and the Cricket paralysis virus IRES). In a related aspect, the third protein can be under the control of the encoded transcription factor or under the control of an inducible promoter.

In one embodiment, the vector system expresses a gene product or protein of interest and a third protein, where the third protein blocks host protein synthesis (FIG. **3**). In a related aspect, the gene product or protein of interest will contain features that prevent their translation from being blocked. In another related aspect, the genes are transcribed by either a constitutive promoter or an inducible promoter.

A kit of the invention is also envisaged. Such a kit can contain a packaging material, for example, a container having a TEE containing oligonucleotide according to the invention and a label that indicates uses of the oligonucleotide for regulating translation of a polynucleotide in an expression vector or other expression construct. In one embodiment, the system, preferably in kit form, provides an integrating expression vector for use in selecting a TEE oligonucleotide using a method as disclosed herein. Such a kit can contain a packaging material, which comprises a container having an integrating expression vector and a label that indicates uses of the vector for selecting oligonucleotide sequences capable of regulatory function.

Instructions for use of the packaged components also can be included in a kit of the invention. Such instructions for use generally include a tangible expression describing the components, for example, a TEE containing oligonucleotide, including its concentration and sequence characteristics, and can include a method parameter such as the manner by which the reagent can by utilized for its intended purpose. The reagents, including the oligonucleotide, which can be contained in a vector or operably linked to an expressible polynucleotide, can be provided in solution, as a liquid dispersion, or as a substantially dry powder, for example, in a lyophilized form. The packaging materials can be any materials customarily utilized in kits or systems, for example, materials that facilitate manipulation of the regulatory oligonucleotides and, if present, of the vector, which can be an expression vector. The package can be any type of package, including a solid matrix or material such as glass, plastic (e.g., polyethylene, polypropylene, and polycarbonate), paper, foil, or the like, which can hold within fixed limits a reagent such as a TEE containing oligonucleotide or vector. Thus, for example, a package can be a bottle, vial, plastic and plastic-foil laminated envelope, or the like container used to contain a contemplated reagent. The package also can comprise one or more containers for holding different components of the kit.

The following examples are intended to illustrate but not limit the invention.

EXAMPLES

Example 1

Experimental Procedures/Materials

Construction of Vectors

The constructs used in the present invention express one or more cistronic mRNAs that encode a transcription factor, protein of interest and/or a protein blocking host protein synthesis. Promoters used to drive transcription of the cistronic mRNAs consist of a minimal promoter (TATA box) or regulatable promoter, alone or in combination with one or more other transcriptional elements, including upstream activating sequences (UAS) and bacteriophage specific promoters. For feedback vectors, a first cistron would comprise a gene encoding a transcription factor, which is inserted downstream from a known or unknown TEE. One such construct, containing a known TEE, would comprise a TATA box promoter element, one or more UAS sequences, and one or more Gtx modules upstream from a cistron encoding Gal4/Vp16.

Example 2

Positive Feedback Reporter Vector for Identifying TEE Elements

Construction

As shown in FIG. **4**, the promoters used to drive transcription in this example comprise a minimal promoter (TATA box) in combination with four copies of the GAL4 upstream activating sequence (UAS). The first transcription unit encodes the GAL4/VP16 fusion protein and the second transcription unit encodes EGFP. The TEE insertion site (denoted by "N" in FIG. **4**) contains nucleotides from a library of 18 random nucleotides. The vector backbone is based on plasmid pHRG-B (Promega, Madison, Wis.). The original BamHI site in pHRG-B was mutated so that both EcoRI and BamHI sites in the TEE insertion site were unique. The random N_{18} fragments are cloned into this reporter vector by using the EcoRI and BamHI restriction sites.

Cell Culture and Transfection Analysis

Reporter constructs are transfected into Chinese hamster ovary cells (CHO) (2×10^4) by using FuGENE 6™ (Roche, Alameda, Calif.). Transfection efficiencies are normalized by co-transfection with a LacZ reporter gene construct (pCMVβ, Clontech, Mountainview, Calif.). Cells are harvested 3 days after transfection and sorted by FACS on a FACSVantage SE™ (Becton Dickinson, Franklin Lakes, N.J.) (Also, see Owens et al., Proc Natl Acad Sci USA (2004) 101:9590-9594). β-galactosidase assays may be performed by methods known in the art. For example, see Chappell et al., Proc Natl Acad Sci USA (2000) 97:1536-1541.

Double-stranded oligonucleotides containing N18 sequences are cloned into the TEE assay site of the positive feedback vector by using EcoRI and BamHI restriction sites. Overnight ligations are performed using T4 DNA ligase at 16° C. The resulting ligation mix is transfected into CHO cells, and FACS analysis is performed as above. For each FACS analysis, the first 100,000 cells are analyzed and a sorting window is drawn to select the cells with the highest EGFP expression. DNA is extracted from cells recovered by FACS and PCR reactions are carried-out by using primers to sequences that flank the EcoRI and BamHI restriction sites. After digestion with both EcoRI and BamHI restriction enzymes, the resulting fragments are re-cloned into the same amplification vector and retested.

For determining the number of plasmids per transfected cell, equal amounts of two plasmids are mixed, CMV-EGFP and CMV-enhanced cyan fluorescent protein (CMV-ECFP; Clontech, Mountainview, Calif.). The cloning vector pBluescript-KS II™ (Stratagene, La Jolla, Calif.) is used as filler for co-transfection. CHO cells are transfected with the different mixtures and FACS analysis is performed 2 days later to assess the expression of both EGFP and ECFP.

All of the compositions and methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of illustrative embodiments, it will be apparent to those of skill in the art that variations may be applied to the composition, methods and in the steps or in the sequence of steps of the methods described herein without

departing from the concept, spirit, and scope of the invention. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. Although the invention has been described with reference to the above examples, it will be understood that modifications and variations are encompassed within the spirit and scope of the invention.

SEQUENCE LISTING

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ggtcagcaga gctgctgata agagccgtat aaagagggtt ccgctcgcaa agatctatgg    180

catgaattcn nnnnnnnnnn nnnnnnngga tcc atg gtg aag ctg tct tct atc     234
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Tyr Ser Pro Lys Thr Lys Arg Ser Pro Leu Thr Arg Ala His Leu Thr
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Phe Pro Arg Glu Asp Leu Asp Met Ile Leu Lys Met Asp Ser Leu Gln
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ctagagtcgg ggcggccggc cgcttcgagc agacatgata agatacattg atgagtttgg    967

acaaaccaca actagaatgc agtgaaaaaa atgctttatt tgtgaaattt gtgatgctat   1027

tgctttattt gtaaccatta taagctgcaa taaacaagtt aacaacaaca attgcattca   1087

ttttatgttt caggttcagg gggaggtgtg ggaggttttt taaagcaagt aaaacctcta   1147

caaatgtggt aaaatcgata aggatcgatc cgtcgagatc tgcgatctaa gtaagcttgg   1207

ctgcaggtcg acggatcgga gtactgtcct ccgagcggag tactgtcctc cgagcggagt   1267

actgtcctcc gagcggagta ctgtcctccg agcggacccc tggcaggagg aaggtcagca   1327

gagctgctga taagagccgt ataaagaggg ttccgctcat ggcaaggggc agtggtctcg   1387

ggatctgagc ttggcattcc ggtactgttg gtaaacc atg gtg agc aag ggc gag    1442
                                        Met Val Ser Lys Gly Glu
                                            230

gag ctg ttc acc ggg gtg gtg ccc atc ctg gtc gag ctg gac ggc gac     1490
Glu Leu Phe Thr Gly Val Val Pro Ile Leu Val Glu Leu Asp Gly Asp
235                 240                 245                 250

gta aac ggc cac aag ttc agc gtg tcc ggc gag ggc gag ggc gat gcc     1538
Val Asn Gly His Lys Phe Ser Val Ser Gly Glu Gly Glu Gly Asp Ala
                255                 260                 265

acc tac ggc aag ctg acc ctg aag ttc atc tgc acc acc ggc aag ctg     1586
Thr Tyr Gly Lys Leu Thr Leu Lys Phe Ile Cys Thr Thr Gly Lys Leu
            270                 275                 280

ccc gtg ccc tgg ccc acc ctc gtg acc acc ctg acc tac ggc gtg cag     1634
Pro Val Pro Trp Pro Thr Leu Val Thr Thr Leu Thr Tyr Gly Val Gln
        285                 290                 295

tgc ttc agc cgc tac ccc gac cac atg aag cag cac gac ttc ttc aag     1682
Cys Phe Ser Arg Tyr Pro Asp His Met Lys Gln His Asp Phe Phe Lys
    300                 305                 310

tcc gcc atg ccc gaa ggc tac gtc cag gag cgc acc atc ttc ttc aag     1730
Ser Ala Met Pro Glu Gly Tyr Val Gln Glu Arg Thr Ile Phe Phe Lys
315                 320                 325                 330

gac gac ggc aac tac aag acc cgc gcc gag gtg aag ttc gag ggc gac     1778
Asp Asp Gly Asn Tyr Lys Thr Arg Ala Glu Val Lys Phe Glu Gly Asp
                335                 340                 345

acc ctg gtg aac cgc atc gag ctg aag ggc atc gac ttc aag gag gac     1826
Thr Leu Val Asn Arg Ile Glu Leu Lys Gly Ile Asp Phe Lys Glu Asp
            350                 355                 360

ggc aac atc ctg ggg cac aag ctg gag tac aac tac aac agc cac aac     1874
Gly Asn Ile Leu Gly His Lys Leu Glu Tyr Asn Tyr Asn Ser His Asn
        365                 370                 375

gtc tat atc atg gcc gac aag cag aag aac ggc atc aag gtg aac ttc     1922
Val Tyr Ile Met Ala Asp Lys Gln Lys Asn Gly Ile Lys Val Asn Phe
    380                 385                 390

aag atc cgc cac aac atc gag gac ggc agc gtg cag ctc gcc gac cac     1970
Lys Ile Arg His Asn Ile Glu Asp Gly Ser Val Gln Leu Ala Asp His
395                 400                 405                 410
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tac cag cag aac acc ccc atc ggc gac ggc ccc gtg ctg ctg ccc gac     2018
Tyr Gln Gln Asn Thr Pro Ile Gly Asp Gly Pro Val Leu Leu Pro Asp
                415                 420                 425

aac cac tac ctg agc acc cag tcc gcc ctg agc aaa gac ccc aac gag     2066
Asn His Tyr Leu Ser Thr Gln Ser Ala Leu Ser Lys Asp Pro Asn Glu
            430                 435                 440

aag cgc gat cac atg gtc ctg ctg gag ttc gtg acc gcc gcc ggg atc     2114
Lys Arg Asp His Met Val Leu Leu Glu Phe Val Thr Ala Ala Gly Ile
        445                 450                 455

act ctc ggc atg gac gag ctg tac aag taacgcgttg actaagctat          2161
Thr Leu Gly Met Asp Glu Leu Tyr Lys
    460                 465

ggcgcgcact aggggctaga gtcggggcgg ccggccgctt cgagcagaca tgataagata   2221

cattgatgag tttggacaaa ccacaactag aatgcagtga aaaaaatgct ttatttgtga   2281

aatttgtgat gctattgctt tatttgtaac cattataagc tgcaataaac aagttaacaa   2341

caacaattgc attcatttta tgtttcaggt tcaggggggag gtgtgggagg ttttttaaag   2401

caagtaaaac ctctacaaat gtggtaaaat cgataaggat cgatccgtcg accgatgccc   2461

ttgagagcct tcaacccagt cagctccttc cggtgggcgc ggggcatgac tatcgtcgcc   2521

gcacttatga ctgtcttctt tatcatgcaa ctcgtaggac aggtgccggc agcgctcttc   2581

cgcttcctcg ctcactgact cgctgcgctc ggtcgttcgg ctgcggcgag cggtatcagc   2641

tcactcaaag gcggtaatac ggttatccac agaatcaggg gataacgcag gaaagaacat   2701

gtgagcaaaa ggccagcaaa aggccaggaa ccgtaaaaag gccgcgttgc tggcgttttt   2761

ccataggctc cgccccccctg acgagcatca caaaaatcga cgctcaagtc agaggtggcg   2821

aaacccgaca ggactataaa gataccaggc gtttcccccct ggaagctccc tcgtgcgctc   2881

tcctgttccg accctgccgc ttaccggata cctgtccgcc tttctccctt cgggaagcgt   2941

ggcgctttct catagctcac gctgtaggta tctcagttcg gtgtaggtcg ttcgctccaa   3001

gctgggctgt gtgcacgaac cccccgttca gcccgaccgc tgcgccttat ccggtaacta   3061

tcgtcttgag tccaacccgg taagacacga cttatcgcca ctggcagcag ccactggtaa   3121

caggattagc agagcgaggt atgtaggcgg tgctacagag ttcttgaagt ggtggcctaa   3181

ctacggctac actagaagaa cagtatttgg tatctgcgct ctgctgaagc cagttacctt   3241

cggaaaaaga gttggtagct cttgatccgg caaacaaacc accgctggta gcggtggttt   3301

ttttgtttgc aagcagcaga ttacgcgcag aaaaaaagga tctcaagaag atcctttgat   3361

cttttctacg gggtctgacg ctcagtggaa cgaaaactca cgttaaggga ttttggtcat   3421

gagattatca aaaaggatct tcacctagat ccttttaaat taaaaatgaa gttttaaatc   3481

aatctaaagt atatatgagt aaacttggtc tgacagttac caatgcttaa tcagtgaggc   3541

acctatctca gcgatctgtc tatttcgttc atccatagtt gcctgactcc ccgtcgtgta   3601

gataactacg atacgggagg gcttaccatc tggccccagt gctgcaatga taccgcgaga   3661

cccacgctca ccggctccag atttatcagc aataaaccag ccagccggaa gggccgagcg   3721

cagaagtggt cctgcaactt tatccgcctc catccagtct attaattgtt gccgggaagc   3781

tagagtaagt agttcgccag ttaatagttt gcgcaacgtt gttgccattg ctacaggcat   3841

cgtggtgtca cgctcgtcgt ttggtatggc ttcattcagc tccggttccc aacgatcaag   3901

gcgagttaca tgatccccca tgttgtgcaa aaaagcggtt agctccttcg gtcctccgat   3961

cgttgtcaga agtaagttgg ccgcagtgtt atcactcatg gttatggcag cactgcataa   4021

ttctcttact gtcatgccat ccgtaagatg cttttctgtg actggtgagt actcaaccaa   4081
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gtcattctga gaatagtgta tgcggcgacc gagttgctct tgcccggcgt caatacggga 4141

taataccgcg ccacatagca gaactttaaa agtgctcatc attggaaaac gttcttcggg 4201

gcgaaaactc tcaaggatct taccgctgtt gagatccagt tcgatgtaac ccactcgtgc 4261

acccaactga tcttcagcat cttttacttt caccagcgtt tctgggtgag caaaaacagg 4321

aaggcaaaat gccgcaaaaa agggaataag ggcgacacgg aaatgttgaa tactcatact 4381

cttccttttt caatattatt gaagcattta tcagggttat tgtctcatga gcggatacat 4441

atttgaatgt atttagaaaa ataaacaaat aggggttccg cgcacatttc cccgaaaagt 4501

gccacctgac gcgccctgta gcggcgcatt aagcgcggcg ggtgtggtgg ttacgcgcag 4561

cgtgaccgct acacttgcca gcgccctagc gcccgctcct ttcgctttct tcccttcctt 4621

tctcgccacg ttcgccggct ttccccgtca agctctaaat cgggggctcc ctttagggtt 4681

ccgatttagt gctttacggc acctcgaccc caaaaaactt gattagggtg atggttcacg 4741

tagtgggcca tcgccctgat agacggtttt tcgccctttg acgttggagt ccacgttctt 4801

taatagtgga ctcttgttcc aaactggaac aacactcaac cctatctcgg tctattcttt 4861

tgatttataa gggattttgc cgatttcggc ctattggtta aaaaatgagc tgatttaaca 4921

aaaatttaac gcgaatttta acaaaatatt aacgcttaca atttgccatt cgccattcag 4981

gctgcgcaac tgttgggaag ggcgatcggt gcgggcctct tcgctattac gccagcccaa 5041

gctaccatga taagtaagta atattaaggt acgggaggta cttggagcgg ccgcaataaa 5101

atatctttat tttcattaca tctgtgtgtt ggtttttttgt gtgaatcgat agtactaaca 5161

tacgctctcc atcaaaacaa aacgaaacaa aacaaactag caaaataggc tgtccccagt 5221

gcaagtgcag gtgccagaac atttctctat cgata 5256

<210> SEQ ID NO 2
<211> LENGTH: 467
<212> TYPE: PRT
<213> ORGANISM: Artificial sequence
<220> FEATURE:
<223> OTHER INFORMATION: Synthetic Construct

<400> SEQUENCE: 2

Met Val Lys Leu Ser Ser Ile Glu Gln Ala Cys Asp Ile Cys Arg Leu
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Lys Lys Leu Lys Cys Ser Lys Glu Lys Pro Lys Cys Ala Lys Cys Leu
20 25 30

Lys Asn Asn Trp Glu Cys Arg Tyr Ser Pro Lys Thr Lys Arg Ser Pro
35 40 45

Leu Thr Arg Ala His Leu Thr Glu Val Glu Ser Arg Leu Glu Arg Leu
50 55 60

Glu Gln Leu Phe Leu Leu Ile Phe Pro Arg Glu Asp Leu Asp Met Ile
65 70 75 80

Leu Lys Met Asp Ser Leu Gln Asp Ile Lys Ala Leu Leu Thr Gly Leu
85 90 95

Phe Val Gln Asp Asn Val Asn Lys Asp Ala Val Thr Asp Arg Leu Ala
100 105 110

Ser Val Glu Thr Asp Met Pro Leu Thr Leu Arg Gln His Arg Ile Ser
115 120 125

Ala Thr Ser Ser Ser Glu Glu Ser Ser Asn Lys Gly Gln Arg Gln Leu
130 135 140

Thr Val Ser Ile Lys Val Ala Pro Pro Thr Asp Val Ser Leu Gly Asp

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145                 150                 155                 160

Glu Leu His Leu Asp Gly Glu Asp Val Ala Met Ala His Ala Asp Ala
                165                 170                 175

Leu Asp Asp Phe Asp Leu Asp Met Leu Gly Asp Gly Asp Ser Pro Gly
            180                 185                 190

Pro Gly Phe Thr Pro His Asp Ser Ala Pro Tyr Gly Ala Leu Asp Met
        195                 200                 205

Ala Asp Phe Glu Phe Glu Gln Met Phe Thr Asp Ala Leu Gly Ile Asp
    210                 215                 220

Glu Tyr Gly Gly Met Val Ser Lys Gly Glu Glu Leu Phe Thr Gly Val
225                 230                 235                 240

Val Pro Ile Leu Val Glu Leu Asp Gly Asp Val Asn Gly His Lys Phe
                245                 250                 255

Ser Val Ser Gly Glu Gly Glu Gly Asp Ala Thr Tyr Gly Lys Leu Thr
            260                 265                 270

Leu Lys Phe Ile Cys Thr Thr Gly Lys Leu Pro Val Pro Trp Pro Thr
        275                 280                 285

Leu Val Thr Thr Leu Thr Tyr Gly Val Gln Cys Phe Ser Arg Tyr Pro
    290                 295                 300

Asp His Met Lys Gln His Asp Phe Phe Lys Ser Ala Met Pro Glu Gly
305                 310                 315                 320

Tyr Val Gln Glu Arg Thr Ile Phe Phe Lys Asp Asp Gly Asn Tyr Lys
                325                 330                 335

Thr Arg Ala Glu Val Lys Phe Glu Gly Asp Thr Leu Val Asn Arg Ile
            340                 345                 350

Glu Leu Lys Gly Ile Asp Phe Lys Glu Asp Gly Asn Ile Leu Gly His
        355                 360                 365

Lys Leu Glu Tyr Asn Tyr Asn Ser His Asn Val Tyr Ile Met Ala Asp
    370                 375                 380

Lys Gln Lys Asn Gly Ile Lys Val Asn Phe Lys Ile Arg His Asn Ile
385                 390                 395                 400

Glu Asp Gly Ser Val Gln Leu Ala Asp His Tyr Gln Gln Asn Thr Pro
                405                 410                 415

Ile Gly Asp Gly Pro Val Leu Leu Pro Asp Asn His Tyr Leu Ser Thr
            420                 425                 430

Gln Ser Ala Leu Ser Lys Asp Pro Asn Glu Lys Arg Asp His Met Val
        435                 440                 445

Leu Leu Glu Phe Val Thr Ala Ala Gly Ile Thr Leu Gly Met Asp Glu
    450                 455                 460

Leu Tyr Lys
465


<210> SEQ ID NO 3
<211> LENGTH: 286
<212> TYPE: PRT
<213> ORGANISM: Artificial sequence
<220> FEATURE:
<223> OTHER INFORMATION: Synthetic construct

<400> SEQUENCE: 3

Met Ser Ile Gln His Phe Arg Val Ala Leu Ile Pro Phe Phe Ala Ala
1               5                   10                  15

Phe Cys Leu Pro Val Phe Ala His Pro Glu Thr Leu Val Lys Val Lys
            20                  25                  30

Asp Ala Glu Asp Gln Leu Gly Ala Arg Val Gly Tyr Ile Glu Leu Asp
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        35                  40                  45

Leu Asn Ser Gly Lys Ile Leu Glu Ser Phe Arg Pro Glu Glu Arg Phe
    50                  55                  60

Pro Met Met Ser Thr Phe Lys Val Leu Leu Cys Gly Ala Val Leu Ser
65                  70                  75                  80

Arg Ile Asp Ala Gly Gln Glu Gln Leu Gly Arg Arg Ile His Tyr Ser
                85                  90                  95

Gln Asn Asp Leu Val Glu Tyr Ser Pro Val Thr Glu Lys His Leu Thr
            100                 105                 110

Asp Gly Met Thr Val Arg Glu Leu Cys Ser Ala Ala Ile Thr Met Ser
        115                 120                 125

Asp Asn Thr Ala Ala Asn Leu Leu Leu Thr Thr Ile Gly Gly Pro Lys
    130                 135                 140

Glu Leu Thr Ala Phe Leu His Asn Met Gly Asp His Val Thr Arg Leu
145                 150                 155                 160

Asp Arg Trp Glu Pro Glu Leu Asn Glu Ala Ile Pro Asn Asp Glu Arg
                165                 170                 175

Asp Thr Thr Met Pro Val Ala Met Ala Thr Thr Leu Arg Lys Leu Leu
            180                 185                 190

Thr Gly Glu Leu Leu Thr Leu Ala Ser Arg Gln Gln Leu Ile Asp Trp
        195                 200                 205

Met Glu Ala Asp Lys Val Ala Gly Pro Leu Leu Arg Ser Ala Leu Pro
    210                 215                 220

Ala Gly Trp Phe Ile Ala Asp Lys Ser Gly Ala Gly Glu Arg Gly Ser
225                 230                 235                 240

Arg Gly Ile Ile Ala Ala Leu Gly Pro Asp Gly Lys Pro Ser Arg Ile
                245                 250                 255

Val Val Ile Tyr Thr Thr Gly Ser Gln Ala Thr Met Asp Glu Arg Asn
            260                 265                 270

Arg Gln Ile Ala Glu Ile Gly Ala Ser Leu Ile Lys His Trp
        275                 280                 285
```

What is claimed is:

1. An multicistronic expression vector suitable for use in a mammalian host cell comprising the following polynucleotide sequences:

a) an isolated first polynucleotide sequence comprising from 5' to 3' direction:

(i) four copies of the GAL4 upstream activating sequence (UAS) comprising nucleotides 19-35, 38-54, 57-73, and 76-92 of SEQ ID NO: 1 and two or more first transcriptional elements comprising a TATA box promoter element comprising nucleotides 148-153 of SEQ ID NO:1, (ii) one or more first translational enhancer elements (TEE) comprising one N18 random oligonucleotide sequence comprising nucleotides 190-207 of SEQ ID NO: 1, and (iii) a first cistron comprising nucleotides 214-897 of SEQ ID NO:1 and encoding a transcription factor, wherein the transcription factor is yeast regulatory protein GAL4/viral protein 16 (GAL4/VP 16), and wherein said N18 is operably linked to the first cistron and increases the amount of GAL4/viral protein induced per unit mRNA; and

b) an isolated second polynucleotide sequence comprising from 5' to 3' direction:

(i) at least one second transcriptional element comprising a TATA box promoter element comprising nucleotides 1347-1352 of SEQ ID NO:1 and four copies of the GAL/UAS comprising nucleotides 1224-1240, 1243-1259, 1262-1278 and 1281-1297 of SEQ ID NO: 1, (ii) at least one second TEE comprising internal ribosome entry sites (IRES) elements, and (iii) a second cistron encoding a second gene product, wherein said TEE is operably linked to the second cistron,

wherein said first and second polynucleotide sequences are functionally linked, wherein upon expression of the GAL4/VP16 in the mammalian host cell, GAL4/VP16 binds to GAL4 UAS sites in the transcriptional element promoters of the first and second polynucleotide sequences, thereby amplifying the transcription of at least the first cistron of the first polynucleotide sequence and the second cistron of the second polynucleotide sequence.

2. The vector of claim **1**, further comprising a third polynucleotide sequence comprising a third cistron encoding a third gene product.

3. The vector of claim **1**, wherein at least one of the two or more first transcriptional elements is not the target of transcription factors endogenous to the host mammalian cell.

4. The vector of claim **1**, wherein the second gene product is a reporter protein, therapeutic protein, an enzyme, an antigen, an antibody, or a structural protein.

5. The vector of claim 4, wherein the reporter protein is selected from the group consisting of GFP, luciferase, β-galactosidase, β-glucuronidase, alkaline phosphatase, chloramphenicol acetyltransferase, ECFP, EGFP, and EYFP.

6. The vector of claim 2, wherein the third gene product blocks host protein synthesis.

7. The vector of claim 6, wherein the third gene product is rotavirus non-structural protein (NSP3), L-proteinase, or proteinase 2A.

8. The vector of claim 6, wherein at least one of the first or second TEEs is resistant to the activity of the product which blocks host protein synthesis.

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